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ARTICLES

THE ASSESSMENT OF SEX IN CREMATED INDIVIDUALS: SOME CAUTIONARY NOTES

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ABSTRACT

Identification of cremated bodies is problematic due to the effect of burning on the tissues of the body. Since hard tissues are altered by burning, it is likely that identification techniques that rely on these tissues will also be affected. The purpose of this study is to examine how heat-induced changes in the hard tissues of the body influence the results of anthropological methods of analysis. Twelve sheep *Os coxae* were burned in a fire-brick furnace. Eight measurements were taken from the sheep *Os coxae* before and after burning. Heat-induced shrinkage was calculated as a percentage. The significance of the differences between the measurements taken before and after burning was assessed statistically (Wilcoxon Signed Rank). The alternative hypothesis, that the difference was significant, was accepted. The influence of heat-induced shrinkage on sex assessment techniques was examined algebraically, then demonstrated with metric methods of sex assessment. The conclusion reached was that uniform shrinkage of the pelvis would not affect metric sex determination techniques, but that differential shrinkage of the variables that comprise the metric sex assessment technique can result in misclassification of male cremated pelves as female, and vice versa.

RÉSUMÉ

Les effets de la chaleur extrême sur les tissus rendent problématique l'identification d'un corps calciné. Puisque les tissus solides sont altérés par la chaleur extrême, il est fort probable que les techniques d'identification basées sur ces tissus en soient aussi affectées. Le but de cette étude est d'examiner comment les changement dûs à la chaleur extrême sur les tissus solides du corps influencent les résultats des méthodes d'analyse anthropologique. Douze moutons *Os coxae* ont été brûlés dans un four en briques réfractaires. Huit mensurations des moutons *Os coxae* ont été prises avant et après exposition à une chaleur extrême. Le pourcentage de rétraction dû à la chaleur extrême a été calculé. La signification des différences entre les mensurations prises avant et après exposition à une chaleur extrême ont été examinées statistiquement (test de rang Wilcoxon). L'hypothèse rivale, c'est-à-dire que la différence était significative, a été acceptée. L'influence de la rétraction provoquée par la chaleur extrême sur la détermination du sexe a été examinée algébriquement et ensuite démontrée par des méthodes de mesure particulières au sexage. En conclusion, la rétraction uniforme du pelvis n'affecte pas les méthodes de détermination du sexe mais une rétraction différentielle des

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variables utilisées pour la détermination du sexe peut résulter en une mauvaise classification du pelvis calciné, c'est-à-dire, mâle au lieu de femelle ou vice versa.

INTRODUCTION

Fire and Forensic Anthropology

There are a number of situations where fire and human corpses can be found in close association. Examples include house and industrial fires, attempts to conceal murder and incriminating evidence, vehicle accidents and acts of terrorism and warfare. It is in these situations that the forensic anthropologist is required to identify the remains of burned individuals. From a forensic perspective, fire is arguably one of the most destructive forces in our society (1). The job of the forensic anthropologist is complicated in these situations because of the serious damage and destruction of both the soft and hard tissues of a corpse as a result of the fire (2). However, it is important to appreciate that it is not possible to completely consume a body by fire (3). Therefore, identification may be possible using the surviving fragments of skeletal material.

Heat-induced alterations of bone fall into one of three categories: alterations in colour, alterations in mechanical strength, and alterations in dimension. Excellent reviews of the causes and influences of these heat-induced alterations are provided elsewhere (for example, 1, 2).

Unfortunately the reliability of standard anthropological techniques, when used to assess cremated bone, may be significantly limited, as their success depends upon the use of unmodified and complete bone dimensions (1, 4, 5). Once the bone has been burned, its dimensions may be altered. Acknowledging this fact, however, age at death has been determined using cremated bone (6-10). Is sex assessment also possible?

Sex Assessment of Cremated Remains

Burned skeletal remains present specific problems when attempting sex assessment. Use of the skull, a staple of most attempts at sex determination, is limited, since it will burst when heated significantly (4, 11). Sex discrimination based on long bone measurements is also less accurate when dealing with burned remains as a result of the changes in dimensions due to shrinkage and warping. In addition, differential burning of the body may cause the extent of shrinkage and warping to vary. This may mean that different bones of the same skeleton may be assigned a different sex. The pelvis survives even extensive burning (4, 11) but can fragment (1). Other methods of sex estimation are still reasonably reliable when applied to cremated remains, for example, the determination of sex related differences in bone wall thickness (12).

Arguably the most complicating effect of burning bone with regard to sex assessment is shrinkage. Heat-induced colour change should not reduce the reliability of sex estimation, as sex assessment techniques do not rely on the colour of the bone for their successful calculation. Heat-induced fragmentation will reduce accuracy, but this is true of all fragmented bone whether burned or not, and certain sex assessment techniques have been developed with fragmented remains specifically in mind. The problem of shrinkage is particularly acute when using metric techniques. Here, shrinkage may result in the misclassification of some males as females (1). Shrinkage obviously reduces the external dimensions of bones, and with male bones this will cause their dimensions to decrease to become more akin to those of female bones. Sex determination is expected to be minimally affected if the bone has not reached 800°C (1), due to the small degree of shrinkage that occurs at temperatures less than this level. Above 800°C, shrinkage is greater and will have a greater effect on metric sex assessment techniques. Standard methodology may, therefore, need to be appropriately altered. For example, a slight lowering of the section points when using discriminant functions has been recommended (1).

The degree to which anthropological techniques of sex determination are affected by burning needs to be quantified so that corrections can be made to them. Two important questions need to be answered before any form of correction can be determined:

1. Is the degree of shrinkage a bone undergoes when burned statistically significant?

2. In what way does shrinkage affect metric sex assessment techniques?

Answering the first question will indicate to anthropologists whether heat-induced shrinkage is significant, and will indicate whether it is likely to affect the outcome of standard sex assessment techniques. The answer to the second question will give a strong indication as to the extent that burning affects the outcome of anthropological analyses. Understanding this is vital before any technique corrections for cremated bone are implemented.

The Experiments

An attempt was made to begin answering the above two questions as part of an MSc research dissertation. The experimental procedure (including justifications for all decisions made), results and conclusions are described in great detail in that work (2). A summary is provided here to provide the context in which the issues discussed below were addressed.

A small (47 cm by 45.5 cm by 47 cm) three-sided fire-brick furnace was constructed in a grass field. A metal grill was placed on top of the structure. A metal sheet was used to cover the open side of the furnace. A mixed softwood and hardwood fuel was placed in the furnace to a height of 20 cm, in a 'log-house' design (11). Twisted newspaper and four firelighter blocks (4 cm by 4 cm by 1.5 cm) were used to speed ignition. The temperature at the centre of the fire was recorded with an Omega HH11 thermocouple machine attached to 1 m of type K stainless-steel sheathed thermocouple wire by a miniature connector. Eleven recently defleshed adult sheep *Os coxae* of unknown sex were collected from a local abattoir and organic butcher. One dry whole adult sheep *Os coxa* of unknown origin was also used.

Eight metric measurements were made on each *Os coxa* using digital sliding callipers precise to 0.01 mm. Each measurement was taken three times before and after cremation, and the mean value was used to reduce observer error. The location of each point of reference used for each measurement was marked on the bone with a scalpel. The eight measurements used, which are standard measurements described elsewhere (13-14), were:

1. length of pubis. Distance from the point in the acetabulum where the three components of the *Os coxa* meet to the superior end of the pubic symphysis (PUB in Tables 1-3).

2. height of ischium. Distance from the point in the acetabulum where the three components of the *Os coxa* meet to the point in which the axis of the ischium crosses the ischial tuberosity (ISC).

3. vertical height of acetabulum. Maximum acetabular diameter from the point where the axis of the ischial body intersects the acetabular rim (ACE).

4. height of pubic symphysis. Distance between the most superior and most inferior points of the pubic symphysis (SYM).

5. height of ischium and acetabulum. Rectilinear distance from the point where the axis of the ischial body crosses the ischial tuberosity to the most distant point on the acetabular rim (IA).
6. greatest length of *Os coxa*. Maximum distance between the most superior part of the iliac crest and most inferior point of the ischial tuberosity (GL).
7. inner length of obturator foramen. Maximum vertical height of the obturator foramen following a superior-inferior axis (LFO).
8. smallest height of the shaft of the ilium. Narrowest distance across the shaft of the ilium (SH).

The *Os coxae* were placed on the metal grill four at a time (ie: both sides of two whole pelves) once the temperature of the fire had reached 180°C. They were placed in a row, on their dorsal side, with the ischium orientated towards the open side of the furnace. The temperature of the fire was recorded every five minutes. The pyre was stirred if the fire subsided. The *Os coxa* bones were removed when they began to calcinate. After removal of the bones, the fire was extinguished with water.

SPSS/PC+ was used to statistically analyse the pre- and post-cremation measurements. Descriptive statistics and percentage shrinkage values were calculated. Due to the lack of Gaussian Normality in the results, Wilcoxon Signed Rank tests were applied to the pre- and post-cremation measurements to test for statistically significant differences between the two data sets. The effect of shrinkage on metric sex assessment techniques was studied algebraically. The following functions were calculated using pre-cremation measurements:

a) the ischio-pubic index = (PUB × 100)/ISC

b) the acetabulum-pubis index = (ACE × 100)/PUB

c) $Y = 22.5888\ (\text{ACE/PUB}) + 0.1196\ (\text{IA}) - 29.3502$

d) $Y = 13.3563\ (\text{ISC}) - 8.2527\ (\text{PUB})$

Percentage shrinkage values were then applied to the pre-cremation measurements and functions a-d were recalculated.

RESULTS

Within the first ten minutes the temperature of the fires had reached approximately 700°C. The highest temperature recorded was 768°C (fire 2). The highest fire temperatures were recorded at the 10-minute mark.

Table 1 contains descriptive statistics on the pre-cremated *Os coxae*. Table 2 describes the data collected from the *Os coxae* after cremation. Table 3 is a summary of the percentage shrinkage data calculated from the pre- and post-cremation data. The data collected from each of the eight pre- and post-cremation measurements were plotted as histograms with normal distribution curves overlaid. As it was clear that the data was not normally distributed, the Wilcoxon Signed Rank test was selected in favour of the paired T-test. The hypotheses for the Wilcoxon Signed Rank test were:

Null: There is no difference between the two sets of measurements

Alternative: There is a difference between the two sets of measurements.

For each of the eight measurements, a statistically significant difference was present. Therefore, in all eight cases, the null hypothesis could be rejected and the alternative hypothesis accepted.

TABLE 1

Statistics Describing the Pre-Cremation Measurements. See Text for Explanation of Abbreviations

	N	Range	Minimum	Maximum	Mean	Standard Error	Std. Deviation	Variance
PRE_PUB	12	31.03	31.44	62.47	48.6167	2.7946	9.6807	93.715
PRE_ISC	12	24.29	80.96	105.25	95.0667	2.0930	7.2504	52.568
PRE_ACE	12	5.78	23.28	29.06	26.4783	0.5507	1.9078	3.640
PRE_SYM	12	25.22	44.22	69.44	61.6075	2.4666	8.5447	73.012
PRE_IA	12	24.38	102.88	127.26	115.0592	2.1219	7.3503	54.027
PRE_GL	12	50.00	198.61	248.61	225.6258	4.6887	16.2423	263.811
PRE_LFO	12	17.90	15.29	33.19	24.3658	1.5763	5.4605	29.817
PRE_SH	12	4.28	10.70	14.98	12.4958	0.3987	1.3811	1.907

TABLE 2

Statistics Describing the Post-Cremation Measurements

	N	Range	Minimum	Maximum	Mean	Standard Error	Std. Deviation	Variance
POST_PUB	9	29.18	30.05	59.23	44.9833	3.4218	10.2653	105.376
POST_ISC	12	39.01	64.30	103.31	86.6958	3.9271	13.6039	185.067
POST_ACE	11	7.77	19.09	26.86	24.0927	0.7125	2.3630	5.584
POST_SYM	10	27.20	39.10	66.30	51.2550	3.0099	9.5182	90.596
POST_IA	12	41.75	82.58	124.33	106.9990	23.8188	13.2287	174.998
POST_GL	9	48.83	198.29	247.12	224.0567	5.7870	17.3610	301.406
POST_LFO	8	18.97	12.57	31.54	20.7912	2.0798	5.8825	34.604
POST_SH	12	4.20	9.70	13.90	11.7225	0.3642	1.2615	1.591

TABLE 3

Statistics Describing the Percentage Shrinkage of the Measurements. Negative Values Indicate the Post-Cremation Measurements Were Greater

	N	Range	Minimum	Maximum	Mean	Standard Error	Std. Deviation	Variance
SHR_PUB	9	16.87	–1.34	15.53	4.9663	1.8565	5.5694	31.018
SHR_ISC	12	28.29	–2.21	26.08	9.1598	2.8318	9.8097	96.230
SHR_ACE	11	21.32	0.38	21.70	9.9585	2.2818	7.5679	57.273
SHR_SYM	10	27.92	1.73	29.65	16.6011	2.8050	8.8702	78.681
SHR_IA	12	27.76	–7.93	19.83	7.2131	2.2652	7.8469	61.573
SHR_GL	9	16.86	–7.77	9.08	2.7384	1.7775	5.3326	28.437
SHR_LFO	8	19.12	4.51	23.63	12.9041	2.5805	7.2987	53.271
SHR_SH	12	19.80	–1.98	17.82	6.0264	1.5968	5.5315	30.598

DISCUSSION AND CAUTIONARY NOTES

- Burning can cause an apparent increase in bone dimensions

On five occasions 'negative shrinkage' was recorded, as the post-cremation measurement increased in size rather than decreased (Table 3). This has been experienced elsewhere (for example, 15, 16). Four of the increases in measurement were found on one bone. In all five cases the increase in size is attributed to warping of the bone, which affected the recording of the measurements.

- The presence of non-normal data

It is probably not surprising that the data collected in this study do not conform to Gaussian normality. Many studies, this one included, have small sample sizes, and standard deviations and ranges for each measurement (especially after cremation) which are quite large. Data collected from the whole population are likely to be normally distributed. If sample data do not achieve a normal distribution arguably the easiest way to rectify this is to make the sample more like the population by increasing its size. Although techniques which use non-Gaussian normal data (such as the Wilcoxon Signed Rank Test) are weaker, they are still of great use. Studies which use statistical techniques without first checking for Gaussian normality are potentially invalidating their conclusions. A study does not suffer because it requires non-parametric tests. Indeed, as is the case here, it will maintain its validity if the correct test is used for the data collected.

- Burning can cause statistically significant dimensional change

It would appear that the variability in the percentage shrinkage values, witnessed as a result of burning (range, minimum and maximum, standard deviation and variance columns of Table 3), has not prevented significant overall differences from occurring. This conclusion has a clear relevance to sex assessment techniques. If the difference between the pre- and post-cremation value is significant (that is, they could be from two separate statistical populations), it would be logical to presume that this would have an effect on the conclusion of any sex assessment technique used on a cremated pelvis.

- The potential misclassification of sex

Previous articles, (1, for example) have suggested that it would be possible to misclassify cremated male pelves as female. This would presumably be due to the decrease in the size of the male pelvis, which would make it appear more feminine. However, this is only entirely acceptable if we concern ourselves with morphological or univariate sex assessment techniques alone. A different, more complicated picture emerges if we wish to concern ourselves with bivariate or multivariate metric techniques. Because an index is size independent, one would not expect it to misclassify males as females simply because of shrinkage. What one would expect is misclassification as a result of changes in the relationship between the two variables (for example the length of the ischium and the length of the pubis). A change in this relationship is only possible if differential shrinkage has occurred in the pelvis, i.e.: if one variable shrinks more than the other.

The effect of differential shrinkage is demonstrated in Table 4. To clarify briefly, x represents the plane of measurement of the numerator of an index (for example, the length of the pubis in Equation a), y represents the denominator (for example, the length of the ischium in Equation a), and z represents the value presented by the index if calculated. If uniform shrinkage occurs (that is, the same percentage of shrinkage along every plane of measurement), it can be seen that no change in z is experienced. However, if x shrinks more than y, the z value will decrease. For example, if x were to shrink by 20% and y by only 5%, the original z value calculated before any shrinkage, would be reduced by 15.8%. If y were to shrink more than x, the value of z would increase. Therefore, because z, the result of an index, can either increase or decrease as a result of the heat-induced shrinkage of the components of an index (x and y), the cremated pelvis can be misclassified either up or down the scale, as either a male or female. With the ischio-pubic index (Equation a), males could be misclassified as females if the pubis shrinks more than the ischium, while females could be misclassified as males if the ischium shrinks more than the pubis. Similarly, with the acetabular-pubic index (Equation b), males could be misclassified as females if the acetabulum shrinks more than the pubis, while females could be misclassified as males if the pubis shrinks more than the acetabulum.

TABLE 4

The effect of shrinkage on the results of bivariate indices. Assume, for example, z = x/y

		x					
		0	–5%	–10%	–15%	–20%	–25%
	0	z	$0.95z$	$0.9z$	$0.85z$	$0.8z$	$0.75z$
	–5%	$1.053z$	z	$0.947z$	$0.895z$	$0.842z$	$0.789z$
	–10%	$1.111z$	$1.056z$	z	$0.944z$	$0.889z$	$0.833z$
y	–15%	$1.176z$	$1.118z$	$1.059z$	z	$0.941z$	$0.882z$
	–20%	$1.25z$	$1.188z$	$1.125z$	$1.063z$	z	$0.936z$
	–25%	$1.333z$	$1.267z$	$1.2z$	$1.133z$	$1.067z$	z

A final consideration is negative shrinkage. If Table 4 was extended to include percentage increases as well as decreases it could be seen that an increase in x relative to y will result in an increase in z, while an increase in y relative to x will result in a decrease in z. However, if it is apparent that an increase in bone dimensions has occurred as a result of heating, it may well be due to warping of the bone, and so the measurement should probably not be used on the grounds of decreased accuracy.

- Correcting for heat-induced shrinkage

A set of correction factors to counter the effects of heat-induced shrinkage is only useful if the percentage by which the bone has shrunk is known. This is unlikely to be the case. The risk of misclassification is great, especially if the temperature of the fire reaches over 800°C (as the extent of shrinkage is greater), and so not using some form of correction factor is inadvisable. However, without knowing the amount of shrinkage suffered, a factor cannot be created. A paradox clearly exists, and further examination is essential.

- Lack of standardisation in cremation studies

An examination of the literature highlights the variety of scientific methods and terms used by workers. Non-standard methodology and terminology can lead to difficulties when attempting to compare different experiments and sets of results. Although standardisation can be inhibited by such factors as financial constraints, an attempt must still be made to make future cremation experiments comparable to existing ones. It may even be of use to produce a uniform glossary, on which all can agree and use.

- Animal Analogues

Animal analogues are often used in cremation experiments. However, some animals clearly have bone that is more akin to human bone than others. Different lifestyles result in different bone properties. How representative of a bipedal human is, for example, a quadrupedal sheep? Unfortunately, experimental sacrifices have to be made for ethical, financial, and logistical reasons. As long as it is acknowledged that an analogue is being used, and that the results achieved from its use may not be fully true of human bone, it is safe to continue.

CONCLUSIONS

Attempting to sex cremated remains is problematic. However, the results from this preliminary study are interesting, and support the need for further investigation. Further work, which would focus on a greater variety of sex assessment techniques and other methods of identification (such as estimating age at death, and stature), is required. New methods of identifying cremated remains may also need to be developed. Until further information is available, the identification of cremated individuals must be done with caution.

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